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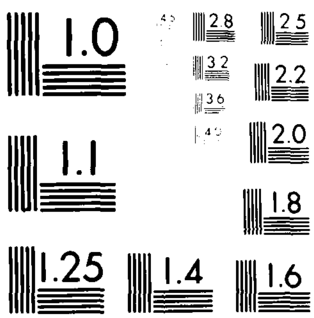

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ENGINEERING AND DEVELOPMENT PROGRAM PLAN
PROPULSION SAFETY

APRIL 1981

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16. Abstract

Assessment of technology advances relative to existing civil aviation regulations indicates that near- and far-term research and development is necessary to resolve potential problem areas and to improve the data base required for proper rule-making. Milestone schedules and recommended funding requirements are included for each task. The five areas of investigation are ingestion, durability, stability, fuels, and materials.

The overall scope of work in safety and reliability involves investigations and evaluations in three major propulsion program subdivisions and one propulsion functional systems program area. These are: aircraft gas turbine engines, aircraft piston engines, helicopter propulsion systems, and propulsion functional systems and components.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

EXECUTIVE SUMMARY

INTRODUCTION.

Periodically, civil aviation powerplants suffer unpredicted failures. Relative to such instances, the number one priority of the Federal Aviation Administration (FAA) Technical Center Propulsion Safety Program is to react to and assist the FAA Headquarters and Regions in the timely investigation, analysis, and solution to these problems. In addition, assistance to other FAA activities in the justification of proposed rulemaking is of prime importance.

During the past 20 years, much progress has been made to advance commercial and general aviation in concert with advancements in engine technology. Recent demanding requirements for engines consuming less fuel, producing significantly less noise and pollution, and ensuring maximum dependability in airline service have brought about rapid development of advanced turbomachinery designs to achieve higher thrust and higher efficiency. The introduction of these newer technology propulsion systems into commercial service must be achieved with an equal or better propulsion safety and reliability than existing capability.

The National Transportation Safety Board (NTSB) continues to report that 24-percent of general aviation accident types are directly or indirectly related to the propulsion system. FAA review of the details of these reported incidents indicate that only 5 percent of the accidents are propulsion oriented, per se. The FAA Technical Center will establish programs designed to understand and reduce the propulsion system related percentage. The FAA Headquarters and Regions will be continually updated on such progress.

This Propulsion Safety Engineering and Development Program Plan has been formulated to accomplish these goals.

OBJECTIVES.

The objectives of the Engineering and Development Program Plan for Propulsion Safety is to:

1. Be responsive to FAA Headquarters and Regions' propulsion related problems in a timely and expert matter.

2. Advise FAA Headquarters and Regions on potential problems.

3. Evaluate upon request of FAA Headquarters and/or Regions, propulsion service difficulties.

4. Contribute solutions to improve propulsion system safety and reliability which will provide a framework for future technology standards.

5. Establish expertise in pertinent fields related to propulsion safety.

ISSUES.

The following are major issues that have been identified by FAA Headquarters and/or the Technical Center:

1. Aircraft Turbine Engines.

   a. Bird ingestion criteria.

   b. Water ingestion criteria.

   c. New production in-service surge margin measurement and definition.

   d. Adaptability of engines to safety fuels.

   e. Containment capability of propulsion systems.

   f. Current engine related in-flight shutdown rate.

   g. Accumulation of an effective propulsion safety and reliability data base.

   h. Wake vortex ingestion capability.

2. Aircraft Piston Engines.

   a. Use of alternate fuels.

   b. Carburetor icing problems.

   c. Engine related general aviation accidents.

3. Helicopter Propulsion System.

   a. All weather capability of propulsion systems.

   b. Hostile environmental effects on engines.

   c. Adequate data base.

4. Propulsion Function Systems.

   a. Effectiveness of power management system.

   b. Component redundancy requirements.

TECHNICAL APPROACH.

In this Propulsion Plan, various project tasks have been defined as either near-term or long-term efforts. The near-term tasks are those work tasks that will be

initiated in the 1981 to 1984 time period to respond to known requirements. These tasks vary in length from 1 to 3 years and can be incrementally funded as work progresses and/or results worthy of additional technical effort are determined.

The long-term tasks are those efforts that can be delayed initially beyond 1983, due to lack of funds or technical expertise, or can be developed as follow-on efforts based on near-term results and recommendations. The long-term tasks can also be initiated in the 1981 to 1984 time period on a low-key basis and then promoted on an accelerated/priority effort basis in the following years. Programs of this type could involve future alternate fuels, variable cycle engines, functional control systems, and composites.

The approach to accomplish the objective will be as follows:

1. Utilization of available background data.

2. Development of new data bases.

3. Development of analytical techniques.

4. Validation of analytical techniques.

5. Cost/benefit analysis of data to determine feasibility for consideration as the basis for regulations, standards, criteria, etc.

SCHEDULE.

Major activities are depicted in figure 1. These are expanded in sections 2 and 3.

PROGRAM MANAGEMENT.

The management of the Propulsion Program will be performed within the Engine/Fuel Safety Branch, ACT-320. The program manager will have overall administration, coordination, and technical responsibility for the execution of the program and all its elements. The major participants within the FAA include but are not limited to:

Office of Systems Engineering Management (AEM)

Office of Aviation Safety (ASF)

Office of Flight Operation (AFO)

Office of Airworthiness (AWS)

New England Region (ANE)

Certain projects will require expertise, facilities and/or scheduling which are beyond current FAA Technical Center capabilities. In order to obtain the most

cost effective and timely results, participation from activities outside of FAA will be requested. These participants will include, but not limited to the following organizations:

United States (U.S.) Air Force/Navy/Army

Arnold Engineering Development Center

National Aeronautics and Space Administration (NASA) Lewis

An informal communication channel will be established between the NASA, Army, Air Force, and Navy Aircraft Propulsion community to exchange data.

FUNDING REQUIREMENTS.

Total program contract funding requirements are as follows:

FY	1980	1981	1982	1983	1984	1985	
TOTAL ($000)	100	358	700	1,390	1,370	1,195	--

MANPOWER REQUIREMENTS.

The milestones contained within this plan are based on effective utilization of in-house engineers and technicians. This manpower will be adjusted within specific tasks as new critical problems arise. The baseline in-house manpower resources required for the plan are as follows:

FY	1980	1981	1982	1983	1984	1985
MY	3	9	9	9	12	12

1. INTRODUCTION.

1.1 PROPULSION AIRWORTHINESS AND SAFETY PROBLEMS.

1.1.1 Gas Turbine Engine Technology Growth.

Since the advent of commercial jet transports, numerous types of gas turbine engines have become widely used. Different engine types have been used and are being considered as powerplants for commercial, business, general aviation aircraft, or rotorcraft. Each engine type has its own particular problems and operating characteristics which affect flight safety, airworthiness, reliability, aborted flights, and/or maintenance requirements. Based on a review of the National Transportation Safety Board (NTSB) accident reports, Flight Standards Service Difficulty Reports (SDR), etc., potential problem areas are identified through close coordination with the lead region.

Current gas turbine engines will continue in service for many years into the future. Newer and more fuel efficient gas turbine engines will continue to be introduced. These engines are expected to employ vastly improved technology to cope with such items as higher turbine inlet temperature, lower turbine cooling flows, increased bypass ratios, increased power extraction levels, etc. Therefore, airworthiness criteria must be reviewed constantly. Where applicable, new requirements should be recommended based upon testing, investigations, evaluations, and/or analysis. The tasks defined in this document, based on current knowledge and projections, should supply sufficient technical information to support the conclusions in each area.

1.1.2 General Aviation Growth.

In the 10-year period (1968-1978), general aviation flying has increased approximately 60 percent in aircraft hours flown and approximately 29 percent in numbers of aircraft flown. During this period, the average number of accidents has decreased approximately 8 percent but the average number of fatalities only decreased approximately 0.5 percent.

For this same time period, the average number of fatal accidents has increased 5.4 percent. NTSB data reports that approximately 24 percent of the most prevalent accident types are related to the propulsion system. The FAA does not concur with this distribution of accident type, as our analysis indicates that the engine caused accidents are approximately 5 percent. One of the critical, propulsion-system related problems is operation in adverse environmental conditions. Both the air and the fuel entering the engine are affected and can produce severe operating conditions for the engines. In addition, cooling air and system temperature effects are considered important contributions toward durability problems. High temperature exhaust systems are critical with regard to material strength and integrity. This area will be evaluated at a later date.

Based on the above, this plan contains projects to be undertaken to evaluate light aircraft piston engines and to establish baseline data for critical environmental conditions along with other factors determined from further analysis. In addition, effort will commence to advance the state-of-the-art with the view toward developing means to minimize the incidence of post-crash fire in general aviation aircraft.

1.1.3 Rotorcraft Growth.

Since World War II, the helicopter has emerged as a useful and highly versatile aircraft demonstrating its application, flexibility, usefulness, and worth for various mission and special operational requirements. These include: support of offshore oil rigs, transportation in and out of congested metro areas, metro law enforcement, traffic control, emergency medical airlift, disaster relief, timber harvesting, and support of construction work in remote areas. Due to this versatility, all-weather certification of helicopters is now being emphasized by manufacturers.

All-weather certification of rotorcraft propulsion systems could result in new problems. Rotorcraft typically utilizes an engine inlet which incorporates foreign object damage (FOD) protection. Criteria governing these features for full anti/icing protection needs development. This effort will be integrated with that noted in the Helicopter Certification Icing Program Plan.

1.1.4 Crash Fire Protection.

The expanding use of the wide-body or jumbo jet aircraft has increased the concern that exists regarding post-crash fires involving aircraft which transport hundreds of passengers in a single aircraft. Post-crash fires involving these aircraft can be of catastrophic proportions, as was tragically demonstrated at Tenerife in 1977. Aircraft, such as these, dictate that safety fuels (antimisting type or equivalent) must be seriously considered and evaluated. If successfully developed, future commercial airliners incorporating the use of safety fuels can minimize the loss of life, equipment, and property due to the post-crash fire. The propulsion system involvement in these post-crash fires must be clearly defined. The problems associated with the use of antimisting fuels, while addressed in reference 1, must also be examined and evaluated under this plan to assure that interaction with the propulsion system is considered. Typical areas of concern are the heat transfer characteristics of the fuel, relative to the oil temperature; effects of the fuel on engine materials, including the oil system components; and the effects of the fuel on hot section components and on the present engine cycles.

1.1.5 Airworthiness Criteria Assessment.

To ensure that commercial and general aviation aircraft powerplants continue to be reliable and safe, it is necessary to maintain updated regulations and standards methodology. This understanding will produce several worthwhile accomplishments: (1) anticipation of changes where necessary, which will improve the current airworthiness code for future propulsion systems; (2) establish testing requirements that will provide the technical data needed to assess regulatory codes; and (3) evaluate new technology advances where appropriate.

1.1.6 The Systems Integration Approach.

Systems integration, with regard to aircraft propulsion systems, relates to the total installed systems. These include the fuel system and its components, the engine and its components, and all of the other support systems, functions, and operational equipment needed to make the entire aircraft function as a unit in a safe, reliable, and airworthy manner.

1.2 PROGRAM OBJECTIVES.

The overall objective of this program is to provide FAA Headquarters and Regions with independent supporting technical data to assess current service problems and to determine the adequacy of current regulations for future engine certification.

The objectives will be accomplished by close coordination with all pertinent FAA suborganizations. The Federal Aviation Administration (FAA) Technical Center will rely upon historical data from various sources. The results of the analysis of such data will lead to an assessment of the Federal Aviation Regulations (FAR) requirements. Sources such as NTSB, FAA's Accident Incident Data System (AIDS) and Service Difficulty Reports (SDR) will be given prime consideration for the construction of this data base. Prime responsibilities for analysis of accident data, AIDS, and SDR rests with the lead region. Research and development effort will be accomplished by contract, interagency agreement, or performed in-house (depending on funding, scheduling and/or on-site technical ability).

1.3 ISSUES.

This plan has been prepared as a result of considering certain issues:

a. Evaluation of proposed technology advancement by engine manufacturers in support of responsible region certification activities.

b. Environmental effects and their impact on future turbine and existing piston engines.

c. Bird ingestion criteria reassessment based on recent service experience.

d. Carburetor icing in light aircraft piston engines testing and evaluation.

e. Power management systems of high bypass ratio engine evaluations to determine their effectiveness with engine deterioration.

f. New antimisting fuel evaluations for general engine compatibility as well as safety with emphasis on engine feasibility, not durability or certification.

g. New production inservice surge margin measurement and definition.

h. Containment characteristics of future propulsion system design evaluations to insure equal or better reliability/safety as demonstrated by current experience.

i. All-weather helicopter operations assessment relative to the effectiveness of powerplant certification.

j. Use of alternate or safety fuels for general aviation assessment.

1.4 PROGRAM TECHNICAL APPROACH.

The tasks delineated within each subprogram element are efforts which define research to support an advisory position and/or technical recommendation on the particular element. Portions of the program can be accomplished at the Technical Center or through outside contracts, including interagency agreements (IA) which allow the FAA the expeditious access to, and use of, other agencies' in-house and contractual capabilities.

As a continuing effort, a current survey of NTSB accident reports, Airworthiness Directives, Advisory Circulars, Advance Notices and Notices of Proposed Rulemaking and their related dockets will be maintained and catalogued. Emphasis will be placed on the use of FAA National Computer data base for accidents, incidents, and service difficulty reports. This compendium of information will be examined to provide a data base for areas of concern and will be used, in part, to establish individual projects such as are listed in this plan. Continuous coordination of such data with other FAA activities will be mandatory.

1.5 PROGRAM STRUCTURE.

This plan provides for a coordinated FAA propulsion airworthiness and safety development effort. It is intended to be a living document with flexibility to respond to and/or anticipate the needs of other FAA activities. It has been structured into the near- and long-term need of four major categories in order to separate specific interest groups. These categories are as follows:

Title	Section
Aircraft Gas Turbine Engine Safety and Reliability	2.1
Aircraft Piston Engine Safety and Reliability	2.2
Helicopter Propulsion System Safety and Reliability	2.3
Propulsion Functional Systems and Components	2.4

Aircraft turbine engine work is subdivided into ingestion, containment, operational and systems areas. Each subtask area is delineated with specific objectives.

The aircraft piston engine effort examines general aviation propulsion system problems. Establishing a data base is of prime importance. Efforts will be made through workshops, meetings, etc., to provide visibility and understanding of general aviation propulsion problems and to develop approaches to their solution.

Helicopter propulsion systems emphasize all-weather certification requirements currently being requested by airframe manufacturers. This effort has been closely coordinated with the overall helicopter all-weather certification review currently in progress at the Technical Center.

Propulsion functional systems efforts emphasize the interaction of the control system on the overall engine performance and power management systems. Engine diagnostic systems are considered relative to their ability to predict critical engine parameter changes.

1.6 INTERAGENCY PARTICIPATION.

In order to be cost effective, this program plan is predicated upon maximum utilization of facilities and ongoing/planned development efforts of other government agencies. In support of this effort, the following assumptions are made:

a. Wherever possible, joint programs with common objectives are and will be utilized in order to preclude costly duplication of efforts and facilities.

b. Effective time scheduling will be based upon availability of government facilities such as those of National Aeronautics and Space Administration (NASA) or Department of Defense (DOD). Therefore, advanced detailed coordination with the facilities will carry a high priority for action.

c. Engines will be available for testing when the need is justified.

d. The FAA will capitalize on test programs of other agencies by establishing and supporting a free flow of interagency information.

e. The program plan does not anticipate the establishment of any additional FAA facility modifications program demands to augment existing facilities.

1.7 MAJOR MILESTONES.

The major milestone of the program elements are summarized in figure 1.

2. PROPULSION SYSTEMS SAFETY AND RELIABILITY DESCRIPTION.

2.1 AIRCRAFT GAS TURBINE ENGINE SAFETY AND RELIABILITY.

Since aircraft gas turbine engines are experiencing a wider appeal for application in various types of aircraft (from large, wide-body multiengine transports to small, business-type aircraft), it has become evident that the FAA needs to expand and further develop its data base and technology with respect to airworthiness criteria.

2.1.1 Objective.

The objective of the propulsion system safety and reliability plan is to substantially increase the general knowledge of, and to document engine safety and reliability. This data can be used to guide improvements to the current and future airworthiness of aircraft gas turbine engines.

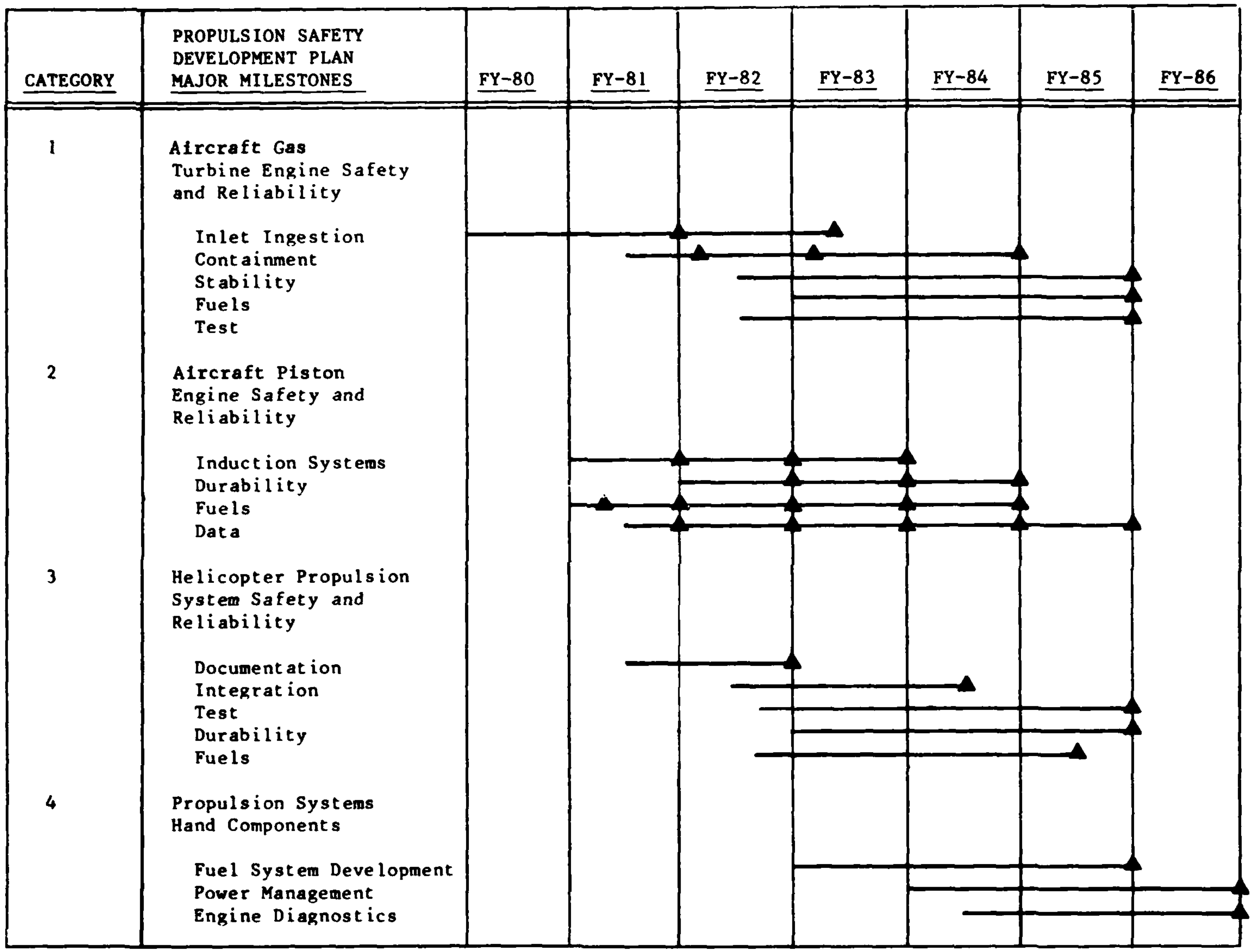

FIGURE 1. MAJOR MILESTONES

2.1.2 Major Tasks.

The tasks defined herein will provide FAA operating services with data to assist in the process of certification for aircraft engine manufacturers. These data must include technical information on operations under normal and abnormal environmental conditions, with the emphasis directed toward assessing airworthiness, safety, and certification procedures.

The tasks are defined in terms of potential problem areas which need to be investigated and evaluated. The data to be collected or obtained as a result of conducting the various tasks will be used to support the solution to aircraft propulsion service problems and revise/improve the regulatory code(s) pertaining to these system(s).

2.1.2.1 Near-Term Tasks.

2.1.2.1.1 Task A — Engine Inlet Ingestion.

Using analysis, scaled testing, and/or representative-type engines, investigate and evaluate bird and water engine ingestion problems.

These investigations and evaluations will provide the technical data needed to assist FAA Headquarters and Regions in their investigation of potential service problems. Federal Aviation Regulation (FAR) part 33, Foreign Object Ingestion, section 33.77, Airworthiness Standards, Aircraft Engines, will be the basic criteria for this task.

2.1.2.1.2 Task B — Durability.

This task will evaluate engine integrity and durability. The first effort will be related to the analysis of uncontained engine failures which have occurred during 1976 through 1980. These results will be analyzed to determine follow-on efforts.

2.1.2.1.3 Task C — Fire Protection.

This task will be undertaken to study, evaluate, and systematically analyze engine induced or related fires. Results of this analysis will determine future areas of effort and the details of the technical approach to be applied.

2.1.2.1.4 Task D — Engine Stability.

This task will be undertaken to identify new production in-service surge margin measurments. The effects of deterioration on the surge margin of these engines will be considered.

2.1.2.1.5 Task E — Fuel(s).

The major task, with regard to determining the usability of antimisting fuels in current and future aircraft propulsion systems (beyond its flammability characteristics in a crash instance), is its compatibility with these systems and the system components. Feasibility tests must be conducted to ascertain the general compatibility of the engine(s) to function satisfactorily and safely with a

selected safety fuel that may be developed to diminish crash-fire hazards. In addition, the aircraft fuel system and its components (pumps, valves, filters, etc.) must be capable of handling this fuel in all flight regimes and during all operating conditions and environments. Engine-mounted fuel system components (fuel control, pumps, filters, pressurizing and dump valves, heat exchangers, etc.) must also be able to handle this fuel without performance degradation or compromising in-flight operation, starting, relite, etc.

The future utilization of reduced flashpoint kerosene, as an aircraft fuel, is becoming more of a possibility due to the energy shortage. The increased volatility of reduced flashpoint kerosene is the most important distinguishing factor from Jet A to determine their effects on safety. It is necessary to test fuels that have this property carefully defined. One objective of this program plan is to determine experimentally how the physical and flammability properties of reduced flashpoint kerosene compare with those of Jet A fuel.

2.1.2.2 Long-Term Tasks.

2.1.2.2.1 Long-Term Engine Test.

Full-scale rig or engine testing, when deemed necessary, will be designed to minimize costs. These tests will explore the current ingestion criteria (both birds and water) as applicable to small diameter high bypass ratio engines. Full-scale engine testing will be preceeded by full-scale compressor and/or fan rig evaluation. Results of this rig testing should dictate the necessity for full-scale engine verification. Long-term effort on other types of engines will be dependent upon the evaluation of critical service related problems.

2.1.2.2.2 Long-Term Fuel System Simulator Rig Test.

Representative aircraft/engine type fuel simulation test rigs, which can be used to evaluate engine fuel system problems, will be employed to identify critical operational problem areas associated with fuel system component performance and antimisting fuel compatability. Attention will be given to component operations at fuel temperature extremes.

2.1.2.2.3 Long-Term Surveillance of Engine Materials.

This effort will be a continuing-type task which will monitor the state-of-the-art progress that is made by government and industry in development of new, advanced materials for aircraft gas turbine engines. The prime purpose of this task will be to catalog their use and application and where possible, expand on the merits and pitfalls.

2.1.2.2.4 Long-Term Evaluation of Future Engine Diagnostic Methods.

Recent advancements in computer technology have brought about more effective use of engine diagnostic systems. These systems, when used in conjunction with current "on-condition-maintenance" concepts, should result in optimum engine utilization while further enhancing engine reliability. This project will identify, define, and assess the impact of these future engine diagnostic systems on maintenance philosophy.

2.1.3 Technical Approach.

The overall technical approach to the aircraft gas turbine engine safety and reliability development effort is described in terms of near-term and long-term project tasks. These tasks will include work by engine manufacturers, universities, other government agencies, and/or FAA Technical Center personnel ulilizing in-house facilities. Certain special test projects may also require the use of FAA flight test aircraft. Projects requiring an in-depth study, evaluation and analysis of current technology, and can be completed in less than 3 years will be performed on a near-term basis.

Projects requiring the evaluation of engine functional systems, such as fuel systems, oil systems, bleed systems, etc., will be performed as both near-term and long-term efforts.

Projects which require lengthy lead times for the procurement of project materials, such as new engine development technology items, will be performed on a long-term basis.

2.1.3.1 Technical Approach — Near-Term Tasks.

2.1.3.1.1 Task A — Engine Inlet Ingestion.

The technical approach for Task A concerns is divided into two areas, bird ingestion and water ingestion.

a. Bird Ingestion — A study of bird ingestion by large high bypass ratio turbine engines will be conducted. The prime objective of this investigation is to obtain statistical samples of the numbers, sizes, and types of birds which are ingested into large high bypass ratio turbine engines during in-service use and what damage, if any, results. This information will be used to determine the effectiveness of the bird ingestion criteria of title 14 of the FAR, paragraph 33.77 regarding in-service operations. Further emphasis on this subject is noted in reference 2.

b. Water Ingestion — Studies will be conducted to determine the effect on engine performance of rain and runway water ingested into turbine engines. Implementation of a multipronged program to determine generalized effects is required. Elements of this effort are:

1. Effects of fuselage water runoff on engine operation. Gross effects of fuselage water runoff will be documented by photographic coverage performed during an aircraft flight test. This flight test will be performed during actual flights through light or moderate rain. Flights through heavy rain will be avoided. Documentation of possible sheeting effects at the face of the engine will be of prime importance.

2. Compressor aerodynamics during transient operation will be investigated, effects of water ingestion on performance will be evaluated. Blockage, pressure loss, distortion, and phase change will be considered.

3. Effectiveness of analytically modeling water ingestion. Fuselage generated engine inlet distortion will be examined by analytical modeling of the aircraft flow characteristics during various flight conditions. A study to

determine the proper similitude parameters applicable to scale model data of engine water ingestion phenomena, including water droplet size and water sheeting from aircraft surfaces will be performed. If feasible, a study using a scaled aircraft model in a wind tunnel will be initiated to validate data obtained from the analytical results.

4. Effects on landing gear water spray on engine operation. Landing gear water spray must have no significant adverse effect on engine operation during the taxi, takeoff, or landing phases relative to runway standing water depths. Recent related problems during certification of small jets have been reported. A study will be made of the factors involved in complying with FAR 25.1091. Is it reasonable to have a set of requirements for small business jet airplanes which comply with FAR 25 and which are separate from the requirements of large air carrier airplanes?

During the development and certification testing of commercial engines, significant effort is expended ingesting water into engines. During these phases, it is not economically or technically feasible to simulate the hostile environment of all conceivable conditions imposed on the engine.

Service experience to date indicates that current certification requirements for water ingestion do insure safe engine operation under reasonable rainfall conditions. Periodically, "what if" questions arise which can only be answered by specifically tailored tests. Such tests are typified by the full-scale engine test program proposed to FAA Headquarters during July 1979. This program involves testing a full-scale engine under sea-level and altitude conditions while an engine is operating at various performance levels and simultaneously ingesting water. Spool down and/or surge characteristics would be of prime concern. Mechanical condition of the engine would be noted through special instrumentation. Such testing results in an exceptionally high expenditure of funds. Therefore, specific objectives and justification are prime requisites, in order that such tailored options be exercised.

2.1.3.1.2 Task B — Durability.

This task will also address uncontained engine failures, which include a continuous comprehensive data search and analysis of past uncontained engine failures. With assistance of the regions, classification of incident consequences will be accomplished in order to identify areas of greatest potential improvement. These studies are directed toward commercial aircraft and include only the fixed-wing type for the present with expansion to other categories being a long-term task.

Improved engine fan-blade fragment containment capability and inlet materials which can better absorb the energy associated with fan-blade fragments will be examined.

2.1.3.1.3 Task C — Fire Protection.

This task will systematically analyze engine induced nacelle fires, as noted in SDR and NTSB reports of accidents or incidents. Evaluation of current engine nacelle fire detection and fire suppression systems shall be included.

In conjunction with the study and evaluation, the adequacy of the nacelle fire detection and fire suppression systems performance, relative to false alarm, will

be of prime importance. Past records, particularly SDR's, indicate that there are considerable in-flight false-fire warning indications which are caused by faulty systems. These false warnings result in unscheduled engine shut-downs, which present potential safety hazards along with increased aircraft logistics problems. The results of these evaluations, analysis, and later tests will be published in reports to aid in the definition of practical criteria that can be considered for incorporation into FAR airworthiness requirements.

2.1.3.1.4 Task D — Stability.

Analytical evaluations will be performed to define possible methods for determining installed surge, flameout, and speed hangup margins for turbofan engines. Computer simulation of a representative turbofan engine and its control system will be considered.

2.1.3.1.5 Task E — Fuels.

Compatibility-type testing will be performed on antimisting fuels which have been screened through initial feasibility tests and which have been deemed as the best currently available. This engine compatibility testing is an integral part of the antimisting fuel program noted in reference 1. Engine fuel system components, in contrast to engine component tested in reference 1, will be evaluated using the selected candidate fuels on flow bench rigs or simulated engine fuel systems. Methods of validating degraded fuel, including the sensitivity of individual engine components to the fuel, will be explored. Flow characteristics and/or visual examination will be used to determine the suitability of the fuel for use in-service.

Full-scale engine feasibility testing will be initiated after the compatibility evaluation has been established. This testing will document potential operational problem areas associated with short-term usage of antimisting fuel. The successful completion of this testing will serve as a major milestone to approve the flight test engine for evaluation, as noted in the reference 1 program plan. There will be continued coordination and integration of all propulsion compatibility efforts related to antimisting fuel.

The effectiveness of the use of low flashpoint kerosene will be evaluated. Safety and handling conditions when fueling aircraft, especially noting temperature at time of fueling will be evaluated. The conditions noted in the survey, along with ullage and ASTM fuel testing results of selected low flashpoint blends of kerosene, some including the antimisting additive, will be examined and a comparison made to fuel flammability results published in reference 4 and will be a prime approach technique.

2.1.3.2 Technical Approach — Long-Term Tasks.

The technical approach of the near-term Task A effort will establish basic data relative to bird strikes on large high bypass ratio engines. The long-term technical approach will use selected portions of the near-term result to establish criteria and parameters needed to investigate bird strikes relative to "small" turbofan engines. The bird strike problem, relative to small turbofan engines, is believed to be significantly different than that of the large engines, due to the sensitivity of system operations to changes in aerodynamic characteristics, i.e.,

reduced core airflow due to blockage or changes to fan airfoil shapes. The ability of the fan to centrifuge birds into the fan air stream together with engine performance changes during bird strike conditions will be evaluated. In-house testing could be performed, if necessary, using a complete engine or a full-scale fan or compressor rig. In such cases, prime consideration would be given to rig testing in lieu of full-scale engine testing because of the added flexibility to test a number of different configurations with reduced operating cost.

A similar long-term technical approach will be used for water ingestion testing. Fan versus core water/air ingestion ratios during uniform and non-uniform water ingestion conditions could be assessed using the same rigs as noted above. Completion of the above full-scale rig evaluation may necessitate full-scale engine testing to verify critical findings. This full-scale engine testing would be confined to specific engine applications which are agreed necessary by the FAA propulsion community.

The long-term technical approach for durability will be centered on containment. Improved inspection and monitoring techniques of engine fan and rotor blades will be emphasized so that impending blade failures are detected and repaired before secondary damage occurs.

Long-term surveillance of engine materials will be accomplished. A materials literature study and a compilation of the latest state-of-the-art data and technical information available from industry and government reference sources will be conducted. A second area of study and investigation will determine the criticality of materials based on their availability. Certain materials used in engines may not be available due to the dependence on foreign supply.

2.1.4 Near-Term Program Schedule and Program Management.

The near-term program schedule for aircraft gas turbine engine safety and reliability is outlined in figure 2. The program management is set forth in section 4.

2.1.5 Funding Requirements.

Aircraft gas turbine engine safety and reliability funding requirements:

FY	1980	1981	1982	1983	1984	1985
TOTAL ($000)	80	318	375	775	800	450

2.2 AIRCRAFT PISTON ENGINE SAFETY AND RELIABILITY.

The expanded growth in general aviation flying during the past 10 years has been matched with an annual increase in the number of accident-related fatalities. As stated earlier, in section 1.1.2, NTSB reports that approximately 24 percent of the accident types are propulsion system related failures/malfunctions. This percentage is misleading because these propulsion system failures have varied from pilot mismanagement of fuel to actual malfunctions/failures in propulsion functional systems and components (cylinder, valve, rod, line-failures, etc.).

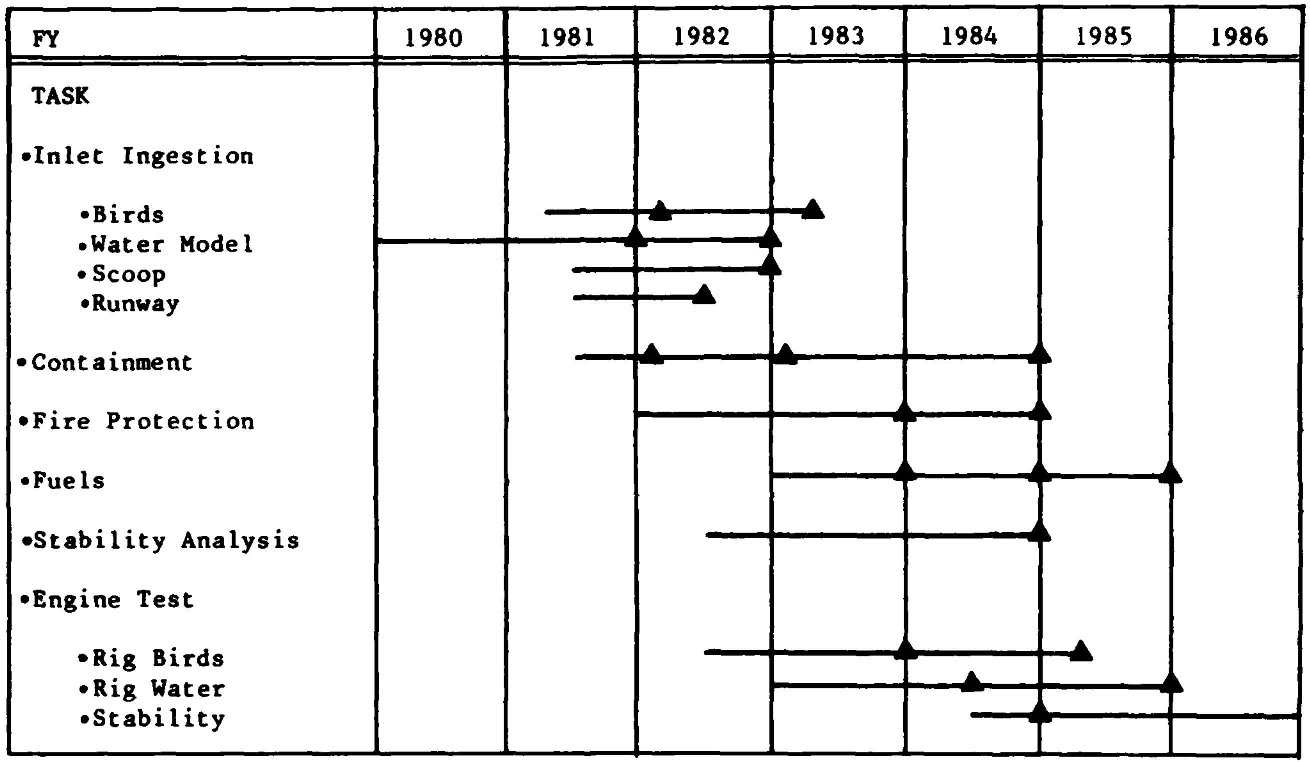

FIGURE 2. GAS TURBINE ENGINE SAFETY AND RELIABILITY

Therefore, this section defines certain important aircraft piston engine project tasks for investigation to advance and expand the current FAA data base on this type of engine and its application requirement(s).

2.2.1 Objective.

The objective of the plan for aircraft piston engines is to substantially increase general knowledge and document how engine safety and reliability data can be used to improve the current and future airworthiness of this class of engines. A greater understanding of the above (by expanding the current data bank and by additional documentation) will provide a criteria on which to base future engine development and for reasonable modifications to current engines.

2.2.2 Major Tasks.

The following tasks will provide the FAA operating services with a data bank to assist in the decision making process on certification requests for aircraft/engines by manufacturers and operators.

This data bank will include technical information on performance of piston engines operating under different normal/abnormal environmental conditions. Such areas of concern are stated in this plan as examples. The fuel used may be similar to current aviation gasolines or modified blends of gasoline that may be more compatible with the energy requirements of tomorrow. An in-depth evaluation of engine in-flight failures and malfunctions can help determine technical approaches to eliminate or reduce these occurrences. Continued research and development to advance the state-of-the-art, with view toward developing better means to reduce the incidence of post-crash fire in general aviation aircraft and the impact of maintenance factors, will be evaluated.

2.2.2.1 Near-Term Tasks.

At present time, the most significant items affecting the overall safety, reliability, and airworthiness of light aircraft piston engines deal with (1) induction system, (2) engine durability, (3) fire protection and (4) fuels. Therefore, four separate project areas covering application of state-of-the-art technology relative to the above items and their impact on airworthiness regulations are presented.

2.2.2.1.1 Task A — Induction System.

Projects in this area concern present day piston engine induction system problems associated with carburetor icing, induction system moisture ingestion, and carburetor anti/deicing. Utilizing representative type certificated engines, this investigation will provide the technical data necessary to assess the airworthiness of existing FAR regulations for present off-the-shelf equipment, and state-of-the-art advancements. As a result, criteria for engine certification and operational limitations for safety requirements may be reassessed.

2.2.2.1.2 Task B — Durability.

An investigation, similar to that discussed under turbine engine durability, section 2.1.3.1.2, will be conducted relative to general aviation aircraft piston engines. Engine durability will be reviewed to ascertain the ability of an engine to resist premature rework prior to scheduled overhaul. Additional items of interest contributing to engine durability are engine/nacelle cooling, lubricating oil effectiveness, and friction reducing compounds.

2.2.2.1.3 Task C — Fire Protection.

An investigation will be made to determine the major factors involved in engine/nacelle/exhaust system fires. This effort will utilize data from the durability task (section 2.2.2.1.2) relative to engine cooling. As part of fire protection, an analysis will be made to isolate causes, prevention modification requirements, detection/extinguishing system types and their respective effectiveness.

2.2.2.1.4 Task D — Fuels.

Investigations will be made to determine if serious hazards and problems are involved in the substitution of auto gas (also known as motor gasoline) in aircraft piston engines in lieu of aviation gasoline. An evaluation task will survey the current state-of-the-art technology of gasoline to determine what significant differences exist between auto gas and 80/87 and/or 100LL aviation gasoline. The following questions will be addressed.

a. *How critical is volatility?*

b. What are the significant additive differences?

c. Can the different methods in determining octane rating be correlated?

d. Is there a compatibility problem when auto gas is burned and the engine continues to use aviation motor oil?

e. How consistent is the production of auto gas across the country?

f. How critical is the water absorption problem?

g. Is the auto gas compatible with aircraft fuel systems/materials?

Investigation of onboard fuel management systems (quantity, flow, etc,) will be made to determine effectiveness.

2.2.2.2 Long Term Tasks.

At this point in time, it appears that the most significant technical advances affecting the airworthiness and overall safety/reliability of aircraft piston engines are the areas of materials and fuels. Therefore, two long-term projects are necessary (1) to investigate and evaluate the impact of applying new metals/materials to small general aviation piston engines, and (2) to determine how the future fuel situation will affect the design of these engines or their future equivalents. The major emphasis of these two long-term efforts would be the

investigation and evaluation of how these technological factors impact the airworthiness of future light aircraft/engine systems.

2.2.2.2.1 Durability.

An investigation is necessary to evaluate benefits that can be derived if new materials are incorporated in future piston engine designs. The material changes to be evaluated would be examined from the standpoint of improved safety. All material changes considered and evaluated must also take into consideration the need to be compatible with any and all fuels and oils that could be certified for use in such engine(s).

The operational environment of engines presents another aspect of long-range durability. Investigations of methods that can be applied to improvement in engine cooling characteristics and limits can impact such durability.

2.2.2.2.2 Fuels.

This project will maintain a long term surveillance and evaluation of the technical advances made in the area of aviation fuels as these advances specifically apply to general aviation needs and requirements. Through this project, the FAA will maintain an active and ongoing program to ensure that any attempts to introduce new fuels (additives or alternate fuels) will not result in compromising airworthiness.

2.2.3 Technical Approach.

The technical approach will be accomplished via contract work by industry, project work by other government agencies under interagency agreements, and in-house efforts; certain special test projects may also require the use of FAA flight test aircraft.

Most of the projects requiring an in-depth study, evaluation, and analysis of current or progressing state-of-the-art technology as pertaining to aircraft piston engines will be accomplished on a near term basis.

Projects requiring test, evaluation, and/or in-depth analysis of futuristic technology will be accomplished as either near-term or long-term efforts, depending upon the scope of work required and the urgency of the need to know.

This section defines the near-term project work as tasks that will be initiated and completed in the 1981 to 1983 time period. Long-term project work, as currently envisioned, will be restricted to tasks in two basic areas — materials and fuels. The long-term work may be initiated in the 1982 time period and will carry over into the 1985 time period. Future long-term projects may also be defined as a result of near-term efforts.

2.2.3.1 Technical Approach — Near-Term Tasks.

The technical approach for Task A, induction systems, will be accomplished by installing a representative-type carburetor aircraft piston engine in sea-level propeller test installations which have the capability to produce water and icing conditions to simulate actual sea-level/low-altitude conditions. The effects of moisture ingestion, carburetor icing, and anti/deicing requirements will be

investigated and evaluated. Ice detectors will be evaluated to determine their effectiveness. Improved methods of detecting carburetor icing will be considered.

The engines used to accomplish the work effort defined under Task A can be used simultaneously to provide cooling data. To accomplish this, the test engine will be installed in representative nacelle configurations. Instrumentation to measure the cooling air pressure differentials, quantities, flow directions, and temperature patterns relative to the engine cylinders will be employed. Correlation with actual flight test data can be accomplished in a follow-on effort, if necessary.

Further expansion of installed engine instrumentation will also provide data to identify critical temperature areas in the nacelle and on the engine. This data will be used in evaluations and analyses of fire protection requirements.

Based on the approaches described herein, it is advisable for parallel programs to be utilized so that an expanded program data base will be developed. Additional engines may include other carburetor, fuel injection, and/or turbocharged types. Follow-on flight test work may be undertaken if test-stand results indicate that such evaluations and development data are needed.

Near-term investigations and evaluations of the current fuel situation dictate analytical efforts similar to Task D. Currently, certain light aircraft pilots and owners are requesting the use of auto gas as an alternate fuel for aviation gasoline. It has been determined that the FAA needs to expand its technical knowledge and understanding of the characteristics and properties of the various fuels available in the marketplace. A better understanding of these fuels requires knowledge of correlation factors, similarities and dissimilarities between fuels, critical fuel parameters, differences in additives and other chemical constituents and properties, etc.

The most important factors that need to be assessed, analyzed, and evaluated are those that directly affect airworthiness. Task D will investigate fuels and evaluate results both from an analytical approach as well as from a practical test and evaluation standpoint, as necessary.

2.2.3.2 Technical Approach — Long Term Tasks.

Aircraft piston engine long-term tasks will be primarily analytical investigations on a surveillance basis to maintain an active knowledge of the state-of-the-art developments in the materials and fuels area. However, it is anticipated that several of the near-term projects may produce technical data requiring that additional follow-on engineering work should be pursued to ensure that airworthiness and flight safety standards are not compromised.

2.2.4 Near-Term Program Schedule and Program Management.

The near-term program schedule for aircraft piston engine safety and reliability is outlined in figure 3. The program management will be set forth in section 4.

2.2.5 Funding Requirements.

Aircraft piston engine safety and reliability program funding requirements are:

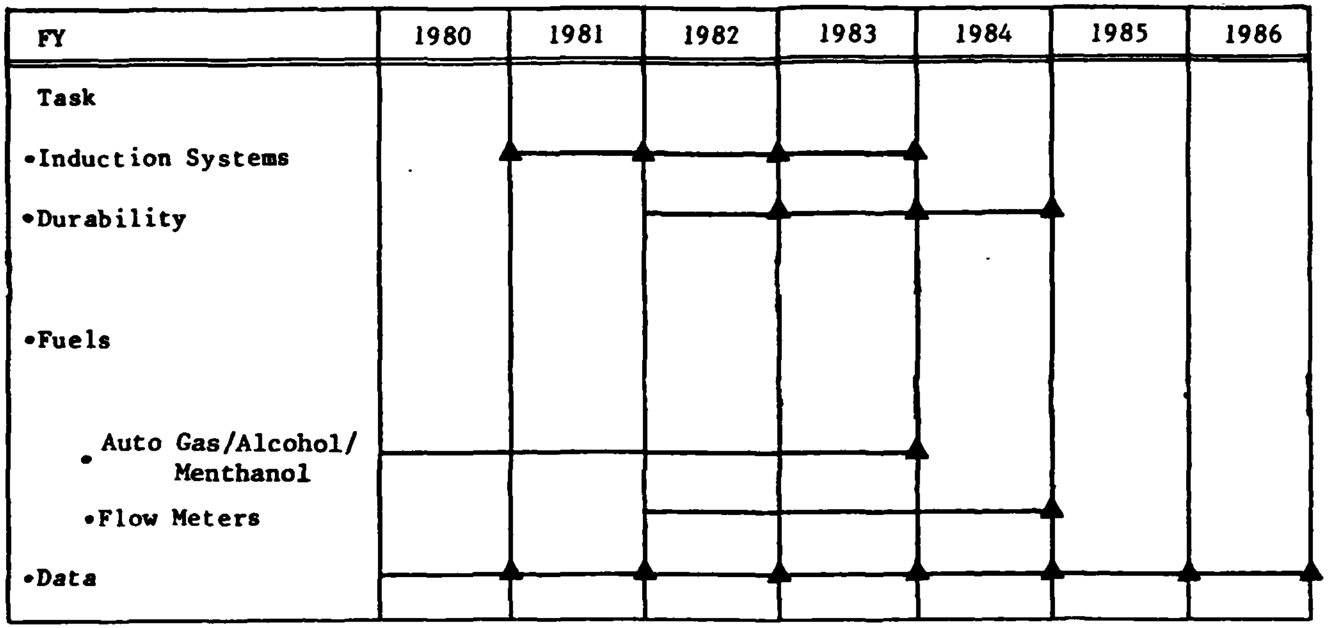

FIGURE 3. AIRCRAFT PISTON ENGINE SAFETY AND RELIABILITY SCHEDULE

FY	1980	1981	1982	1983	1984	1985
TOTAL ($000)	20	40	200	190	220	320

2.3 HELICOPTER PROPULSION SYSTEM SAFETY AND RELIABILITY.

The turboshaft engine has become the principle powerplant to provide the driving power for the transmission and rotor systems of helicopters developed since 1960. Therefore, this section will address only turboshaft engines in helicopter applications. Powerplants used for helicopters must meet the requirements for FAR Part 33. The turbine aircraft engine criteria in Part 33 is essentially the same for conventional fixed wing aircraft and rotorcraft.

Engines for fixed-wing aircraft certified to FAR 33 criteria have operated successfully with relatively few accidents or incidents, even in all-weather operations. Rotorcraft engines certified to this criteria have demonstrated successful operation within the current rotorcraft environmental envelope; however, rotorcraft have been limited to visual flight rules (VFR) certifications. Recent helicopter Instrument Flight Rules (IFR) certification developments and the desire of civil operators to obtain near all-weather helicopter capabilities, may have introduced a new spectrum of powerplant problems.

2.3.1 Objective.

The objective is to develop a data base to investigate, evaluate, and analyze environmental factors affecting rotorcraft propulsion system operations under "all-weather" conditions, and to assess the potential impact of these factors on the requirements of FAR, Part 33.

2.3.2 Major Tasks.

2.3.2.1 Near-Term Tasks.

2.3.2.1.1 Task A — Documentation.

This task will provide the FAA with a technical data bank specifically tailored to helicopter powerplant operations. The data bank will catalog helicopter engine models and types together with other uses of the same engine, inlet configurations, protection configurations, and engine airflow. This information will be used to determine a baseline for rotorcraft propulsion all-weather certification requirements. Areas of potential concern will be highlighted.

2.3.2.1.2 Task B — Integration.

This task will combine the results of Task A with the continuing data being generated from the Engineering and Development Program Plan for Helicopter Icing Certification Research (reference 3). Selected rotorcraft installations will be compared to Task A results. System integration, with regard to helicopter propulsion systems, will relate to the total engine inlet configuration and will attempt to establish the condition of the air entering the engine during hostile environmental conditions. Meteorological criteria developed from reference 3 will

be assessed to determine possible problem areas unique to categories of helicopter propulsion systems. Ice protection systems and helicopter mission profiles shall be included.

This task will further analyze the meteorological criteria being developed and determine its relevancy to the independent engine certification requirements of FAR 33. Emphasis will be placed on that portion of FAR 33, and referenced FAR 25, which deals with ice, water, and snow ingestion.

2.3.2.1.3 Task C — Durability.

This task will review helicopter propulsion related accidents and reported in-service problems, such as bird ingestion, water ingestion, compressor failures, etc. This durability program will utilize FAA's existing systems of AIDS and SDR. This information will be analyzed, relative to FAR requirements, to identify helicopter engine problems. The objective of this task is to determine the severity and frequency of propulsion in-service difficulties and provide the basis for future candidate propulsion research needs.

2.3.2.2 Full-Scale Testing.

The helicopter propulsion system safety program defined in this plan is designed to capitalize on the FAA Technical Center's helicopter icing certification program (reference 3). The results of Task B above will provide results based on analysis Validation of these results will be required. Full-scale propulsion system testing may be required to provide validation creditability. The validation of propulsion related areas will use selected simulators, full-scale systems or rigs being planned within the helicopter icing certification program as the prime approach toward cost effective results. This piggy-back method will be accomplished through effective coordination within the Technical Center.

2.3.2.3 Fuel(s).

Turboshaft engines are designed to use the same fuel as other aircraft gas turbine engines. Therefore, this task will be conducted concurrently with Task E (section 2.1.2.1). Safety fuels will be evaluated to determine compatibility with types of engines and with the total rotorcraft fuel system.

2.3.2.4 Fire Protection.

This task will be conducted to evaluate engine installation fires in helicopters. It will expand upon the results of the near-term Task C durability noted above. Investigation into FAR 25 requirements relative to fire protection/fire detection and fire suppression will be conducted to identify differences which are peculiar to turboshaft type engine installations coupled with rotor downwash. The objective is to define design criteria and design guidelines that can be promulgated to improve engine airworthiness.

2.3.3 Technical Approach to Near-Term Tasks.

The technical approach to Task A, documentation, is to document helicopter propulsion configurations by cataloging significant propulsion related characteristics. Engine and helicopter manufacturers and other sources, where applicable,

will be surveyed to supply basic data such as inlet configuration, type of separators, critical dimensions, engine airflow and bleed characteristic and deicing requirements. This data will be cataloged and analyzed by the FAA Technical Center with differences and similarities highlighted.

The technical approach to Task B, integration, is to assess the results of helicopter meteorlogical icing criteria being developed within the FAA Technical Center by correlating the data to propulsion related parameters. The cataloged data from the "documentation" task will be used to characterize these specific rotorcraft parameters. Emphasis will be placed on icing protection effectiveness and water ingestion limitations within the constraints of the selected helicopter mission profile. The results of this rotorcraft propulsion system analysis for specific applications will be compared to FAR, Part 33. Level of differences will be assessed and severity of effects ascertained.

The technical approach to Task C, durability, is to utilize FAA's existing Aviation Safety Analysis System. Rotorcraft powerplant information is available within this system under the programmed AIDS and SDR. This rotorcraft powerplant problem data base will be statistically analyzed to identify engine and engine installation areas for investigation. This dynamic data base will consider such factors as frequency and severity as a minimum. This data will be used to establish the need and/or priority for future rotorcraft research effort.

2.3.4 Technical Approach — Long-Term Tasks.

The technical approach for the long term "full-scale testing task" is to implement a full-scale testing of selected systems to validate significant conclusions reached in near-term Task B. The helicopter icing certification plan, reference 3, encompasses numerous simulator and/or full-scale development testing. It is the intent within the helicopter propulsion system safety section of this plan to effectively use the existing helicopter icing certification tools noted in reference 3, paragraph 2.4. Effective coordination within the FAA Technical Center is mandatory. To this end, objectives and test plans will be coordinated to insure the most cost effective utilization of resources.

The technical approach for the long-term "fuels" task is to analyze data being provided within the antimisting fuel program plan, reference 1. In order to establish the applicability of the use of antimisting fuel to the civil aviation fleet, surveys of engines, aircraft, and rotorcraft are in process. These surveys encompass both existing and anticipated systems. System characteristics such as fuel temperatures, pressures, and filter sizes will be defined. Results of these surveys, as related to rotorcraft, will be analyzed to determine critical areas which may be effected using antimisting fuel. Component bench testing will be employed to verify critical operational problem areas associated with the use of antimisting fuel.

Technical approach to fire protection in helicopter turboshaft systems will involve a statistical analysis of the records compiled in the two existing programs of AIDS and SDR identified under the technical approach of short-term Task C. Fire problems identified will be investigated with the FAA Flight Standards Service and with the manufacturers to ascertain if adequate action has been taken to eliminate the problem. If problems exist, a controlled test program will be initiated to address a solution to the fire problem. Final technical reports will cover the results.

2.3.5 Program Schedule and Program Management.

The program schedule for helicopter propulsion system safety and reliability is outlined in figure 4. The program management is set forth in section 4.

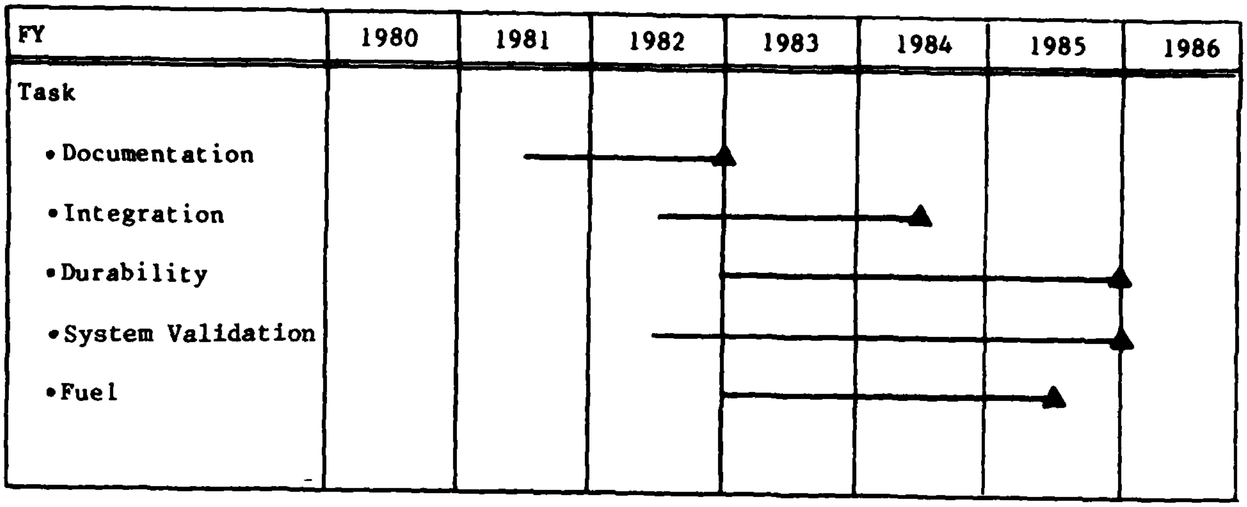

FIGURE 4. HELICOPTER PROPULSION SYSTEM SAFETY AND RELIABILITY SCHEDULE

2.3.6 Funding Requirements.

Helicopter propulsion safety and reliability program funding requirements are:

FY	1980	1981	1982	1983	1984	1985
TOTAL ($000)	0	0	125	175	150	125

2.4 PROPULSION FUNCTIONAL SYSTEMS AND COMPONENTS.

The aircraft/propulsion functional systems have become more complex in the last 15 to 20 years. Consequently, their reliability and functional integrity have become more of a technical challenge. These factors have become even more complex because modern aircraft functional systems, particularly propulsion systems, are being designed to incorporate mechanical and electronic features for effective power management. Some of this complexity has come about as a result of airworthiness and flight safety requirements which require redundant and fail-safe features. These safety features of functional control systems must be analyzed, and criteria to assure compatibility with FAR requirements established.

This section of the development plan is designed to investigate, through analysis, major propulsion functional systems to define the required control factors, parameters and characteristics, and their functional impact on propulsion system safety margins.

2.4.1 Objective.

The objective is to investigate three major areas in which functional systems and their components have a major significant impact on airworthiness and flight safety. The three major areas are fuel system controls, power management, and engine diagnostic systems.

From the FAA's standpoint, it is necessary to evaluate the degree of complexity that can be permitted without compromising airworthiness and flight safety. What fuel system components can be affected by future changes in fuels and fuel characteristics? What diagnostic system advances have been made in recent years that could be incorporated in aircraft/propulsion system surveillance or onboard warning systems to improve airworthiness and flight safety?

2.4.2 Major Tasks.

The major tasks, mentioned above are defined as long-term tasks and are discussed individually in the following:

a. Fuel System Controls — The investigation of fuel system controls will concern itself primarily with evaluation of (1) how antimisting-type fuel may influence the functional performance of fuel system controls that are currently in existence and (2) what new features need to be incorporated into the fuel system controls to accommodate antimisting-type safety fuels. Fuel level controls need to be assessed, transfer systems need to be evaluated, and fuel shutoff system characteristics need to be determined. Effects of full authority electronic control systems, in lieu of currently incorporated hydromechanical control systems, needs to be assessed.

b. Power Management — The technical approach will be to examine representative turbine engine types to categorize and relate the different power management systems used by the manufacturers. Testing a small, high bypass ratio engine will give a comparison of the effectiveness of the power management system. This effectiveness testing will also serve as a reference point of stability testing. This will be done on a sea-level engine test stand. The general scope of this test will be to measure thrust, airflow, and related parameters of a new engine. The engine will then be modified to represent maximum deterioration conditions allowed by the manufacturer's maintenance manual, i.e., blade cracks, rotor clearances, etc. Numerous engine power management methods will be evaluated on the baseline new engine and repeated on the deteriorated engine. Effects on engine stability, relative to engine surge margin changes, will be considered during this back-to-back testing.

c. Engine Diagnostic System — Airborne diagnostic system needs to be investigated to determine if their use will significantly contribute to extended engine life without compromising operational integrity. Criteria for assessment of the various concepts and their interaction to FAR requirements will be developed.

2.4.3 Technical Approach.

The technical approach to investigate and evaluate propulsion-oriented functional systems will include a study and analysis of various types of systems that are being utilized in current aircraft/propulsion systems. This study will establish the current state-of-the-art technology, so that proposed technology ideas, designs, innovations, etc., for future applications can be evaluated. Comparisons will be made of such system characteristics as accuracy response, sensitivity to outside interference (both electrical and dynamic), and maintainability. This information will provide historical and technical data, which will ensure that functional systems will be designed reliably with no impact on operational safety.

2.4.4 Program Schedule and Program Management.

The program schedule for propulsion functional systems and components is outlined in figure 1, Major Milestones. The program management will be set forth in section 4.

2.4.5 Funding requirements.

The propulsion functional systems and component development program funding requirements are:

FY	1981	1982	1983	1984	1985
TOTAL (0000)	0	0	250	200	300

3. FUNDING REQUIREMENTS.

Funds required to provide for the timely development of propulsion system safety and reliability data, reports, and criteria for upgrading and improving the airworthiness standards are identified in table 1. The breakdown of funding requirements is provided on the basis of major subprograms under the four propulsion systems categories, sections 2.1, 2.2, 2.3, and 2.4, of this plan.

Table 1 does not provide funding estimates for the purchase and/or lease of major equipment items such as large engines, nacelles, fuel systems, air frames, etc. Funding to purchase or lease such equipment will be requested as future priorities to justify their need.

4. PROGRAM MANAGEMENT.

4.1 GENERAL.

The Propulsion Safety Engineering and Development Program Plan will be managed within the organizational structure and available manpower resources of the Engine/Fuel Safety Branch, ACT-320, Aircraft Safety Development Division, FAA Technical Center.

TABLE 1. SUMMARY OF FUNDING REQUIREMENTS
($000)

SUBSECTION	TASK	FY 1980	1981	1982	1983	1984	1985
2	Propulsion System Safety and Reliability Plan						
2.1.2.1	Inlet Ingestion	80	280	300	150	100	50
	Containment	--	38	75	75	--	--
	Fire Protection	--	--	--	--	50	
	Engine Stability	--	--	--		75	--
	Fuels	--	--	--		75	100
	Engine Tests						
	Rig Birds	--	--	--	275	200	
	Rig Water	--	--	--	275	200	100
	Stability	--	--	--	--	100	200
2.2.2.1	Induction System	20	20	70	50	50	
	Durability	--	--	--	--	--	100
	Fuels						
	Auto Gas/Alcohol/Methanol	--	--	70	100	150	200
	Flow Meters	--	--	30	20	--	--
	Data	--	20	30	20	20	20
2.3.2.1	Durability	--	--	--	--	50	50
	Full Scale Test Support	--	--	75	75	50	75
	Fuel System	--	--	50	100	50	--
2.4.2	Fuel System Develop	--	--	--	100	100	100
	Power Management System	--	--	--	150	100	100
	Engine Diagnostic	--	--	--	--		100

Overall policies, requirements, etc., will be in concurrence with FAA Headquarters overall directives, policies, and requirements. Coordination of the significant overall objectives within this plan will be accomplished within NASA and DOD propulsion communities.

4.2 PROGRAM COORDINATION.

Program coordination with all participants and elements involved in the planning and execution of the Propulsion Safety Engineering and Development Program Plan involves identification of both technical and support requirments and personnel, allocation of resources and facilities, initiation and coordination of interagency and international agreements, integration of related efforts of other agency programs, and continuation of dialogue with all civil operating and industrial entities and their representatives to ensure that the Program Plan is relevant to current and projected needs. Coordination with industry, NASA, FAA Headquarters, Regions, etc., of program directions, revisions, and results will be a continuing effort.

The overall technical approach on the effects of engine stability and the related change in surge margin of deteriorated engines noted in section 2.1.3.1.4 will include a continuing exchange of information and data between FAA Technical Center, NASA, and DOD Propulsion Specialists.

5. *REFERENCES*.

1. Engineering and Development Program Plan, Antimisting Fuel, FAA-ED-18-4, FAA Technical Center, September 1980.

2. Bird Ingestion, Transportation Safety Board Letter to FAA Administrator, regarding NTSB safety recommendation A-76-64, dated, July 30, 1980.

3. Engineering and Development Program Plan Helicopter Icing Certification, FAA-ED-18-8, FAA Technical Center, August, 1980.

4. Aviation Fuel Safety — 1975, Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York, New York 10020.

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